Report for 2005NY69B: Protecting future quantity and quality of New York State's water resources under changing climatic conditions

Publications

- Articles in Refereed Scientific Journals:
  - Siepel, A.C.; T.S. Steenhuis; C.W. Rose; J.Y. PArlange; G.F. McIsaac, 2002, A Simplified Hillslope Erosion Model with Vegetation Elements for Practical Applications, Journal of Hydrology, In Press.
  - Mendoza, G.; T.S. Steenhuis; 2002, Determination of Hydraulic Behavior of Hilsides with an Hillslope Infiltrometer, Soil Science Society of America Journal, In Press
  - Stomph, T.J.; N. De Riddle; T.S. Steenhuis; N.C. van de Griesen; 2002, Scale Effects of Hortonian Overland Flow and Rainfall Runoff Dynamics: Laboratory Validation of a Process based Model, Earth Surface Processes and Landform, In Press.
  - Akhtar, M.S.; T.S. Steenhuis; P.A. Medrano; M. deGroot; B.K. Richards; 2002, Is Soil Phosphorus Transport Related to Absorption Strength? Soil Science Society of America Journal, In Press.
  - Masiyandima, M.C.; S. Diatta; N. van de Giesen; P.N. Windmeijer; T.S. Steenhuis; 2002, the Hydrology of Inland Valleys in the Sub-Humid Zone West Africa: Runoff Processes in the M'be Experimental Watershed, Hydrol. Proc., In Press.
  - Geohring L.D.; O.V. McHugh; M.T. Walter; T.S. Steenhuis; M.S. Akhtar; M.F. Walter; 2001, Phosphorus Transport into Subsurface Drains by Macropores after Manure Applications: Implications for Best Manure Management Practices, Soil Science, 12:896-909.
  - Darnault, C.J.G.; D.A. DiCarlo; T.W.J. Bauters; A.R. Jacobson; J.A. Throop; C.D. Montemagno; J.-Y. Parlange; T.S. Steenhuis; 2001, Measurement of Fluid Contents by Light Transmission in Transient Three-Phase Oil-Water-Air Systems in Sand, Water Resour. Res., 37:1859-1868.
  - Steenhuis, T.S.; J. Caledro Rivera; C.J. Martinez Hernandez; M.T. Walter; R.B. Bryant; P. Nektarios; 2001, Water Repellency in New York State Soils, International Turfgrass Society Res. Journal, 9:624-628.

- Stagnitti, F.; L. Li; D.A. Barry; G. Allinson; J.-Y. Parlange; T.S. Steenhuis; E. Lakshmanan; 2001, Modeling Solute Transport in Structured Soils: PErformance Evaluation of ADR and TRM Models, Mathematical and Computer Modeling, 34:433-440.
- Heilig, A.; D. DeBruyn; M.T. Walter; C.W. Rose; J.-Y. Parlange; T.S. Steenhuis; G.C. Sander; P.B. Hairsine; W.L. Hogarth; L.P. Walker; 2001, Testing a Mechanistic Soil Erosion Model with a Simple Experiment, Journal of Hydrology, 244:9-16.
- Walter, M.T.; M.F. Walter; E.S. Brooks; T.S. Steenhuis; J. Boll; K.R. Weiler; 2000, Hydrologically Sensitive Areas: Variable Source Area Hydrology Implications for Water Quality Risk Assessment, Journal of Soil Water Conservation, 3:277-284.
- Parlange, J.-Y.; F. Stagnitti; A. Heilig; J. Szilagyi; M.B. Parlange; T.S. Steenhuis; W.L. Hogarth; D.A. Barry; L. Li; 2001, Sudden Drawdown and Drainage of a Horizontal Aquifer, Water Resources Res., 37:2097-2101.

- Conference Proceedings:
  - Steenhuis, T.S.; Y.-J. Kim; J.-Y. Parlange; M.S. Akhtar; B.K. Richards; K.-J.S. Kung; T.J. Gish; L.W. Dekker; C.J. Ritsema; S.A. Aburime; January 3-5, 2001, An Equation for Describing Solute Transport in Field Soils with Prefential Flow Paths, in Preferential Flow, Water Movement and Chemical Transport in the Environment, Proc. ASAE 2nd International Symposium, Honolulu, HI, 137-140

Report Follows

Protecting Future Quantity and Quality of New York State's Water Resources Under Changing Climatic Conditions

Control of phosphorus and nitrogen (P and N) loss from agricultural landscapes is important because P is widely recognized as a primary cause of eutrophication of inland waters and N has a direct effect on the degradation of costal waters. Moreover, although the northeastern US receives sufficient rainfall in most years in drought years many regional municipalities face a severe shortfall in drinking water. Protecting our water resources in the future will require comprehensive understanding and knowledge about how foreseeable climate extremes will affect both water quality and quantity. Since essentially all the current water quality models were developed for Midwestern US conditions, these models need to be adapted to the hydrologic and climatic conditions of the Northeast to be trustworthy in New York State.

This research is especially important for New York City (NYC) since eight million people depend on water collected in the Catskills. Moreover, the in the Catskills region of New York State, excessive P loading to the Cannonsville Reservoir, which supplies drinking water to New York City, has led to wastewater discharge restrictions that limit economic development in local communities. This scenario is indicative of many of the region's municipalities.

The overall goal of the proposed work is to contribute to the improvement of surface and ground water quality in the northeastern US and to study the effects of possible future climate changes on water quality and quantity. The proposed research will be carried out in the Cannonsville Reservoir Basin, of which the Town Brook and Trout Creek watersheds are representative subwatersheds that the project team is currently monitoring. These watersheds, in the NYC drinking water source system, are typical of the northeastern US.

Accomplishments

The past year we have formulated in cooperation with both USDA-ARS (Penn State) and NYCDEP, watershed models that are valid for the unique characteristics of the northeastern US, including variable source area (VSA) hydrology. These models, developed at several levels of complexity, are capable of evaluating the temporal and spatial distribution of water and nutrients within the watershed. The model that is conceptually the simplest is based on the SCS-curve number (CN) equation that is used in many water quality models to predict storm runoff from watersheds based on an infiltration-excess response to rainfall. However, in humid, well-vegetated areas with shallow soils, such as in the northeastern US, the predominant runoff generating mechanism is saturation-excess on variable source areas (VSAs). We re-conceptualized the SCS-CN equation for VSAs, and incorporated it into the General Watershed Loading Function (GWLF) model. The new version of GWLF, named the Variable Source Loading Function (VSLF) model, simulates the watershed runoff response to rainfall using the standard SCS-CN equation, but spatially-distributes the runoff response according to a soil wetness index. We spatially validated VSLF runoff predictions and compared VSLF to GWLF for a sub-watershed of the New York City Water Supply System. The spatial distribution of runoff from VSLF is more physically realistic than the estimates from GWLF. This has important consequences for water quality modeling, and for the use of models to evaluate and guide watershed management, because correctly predicting the coincidence of runoff generation and pollutant sources is critical to simulating non-point source (NPS) pollution transported by runoff. The results of this effort are written up in Schneiderman et al (2006) which is in press

A more complicated procedure is the Soil Moisture Routing and Distribution model. This is a physically-based, fully-distributed, GIS-integrated model, developed to simulate the hydrologic behavior of small rural upland watersheds with shallow soils and steep to moderate slopes. The model assumes that gravity is the only driving force of water and that most overland flow occurs as saturation excess. The model uses available soil and climatic data, and requires little calibration. Funding was used for running the SMDR model to simulate runoff production on a 164-ha farm watershed in Delaware County, New York, in the headwaters of New York City water supply. Apart from land use, distributed input parameters were derived from readily available data. Simulated hydrographs compared reasonably with observed flows at the watershed outlet over a eight year simulation period, and peak timing and intensities were well reproduced. Using off-site weather input data produced occasional missed event peaks. Simulated soil moisture distribution agreed well with observed hydrological features and followed the same spatial trend as observed soil moisture contents sampled on four transects. Model accuracy improved when input variables were calibrated within the range of SSURGO-available parameters. The model will be a useful planning tool for reducing NPS pollution from farms in landscapes similar to the Northeastern US. The paper was published for discussion by Gerard Merchant et al. (2005). Based on these discussions the full paper is now in press as Gerard Merchant et al. (2006)

In addition a spatially distributed model of total dissolved phosphorus (TDP) loading was developed using raster maps covering a watershed with 164-ha dairy farm. Transport of TDP was calculated separately for base flow and for surface runoff from manure-covered and non-manure-covered areas. Soil test P, simulated rainfall application, and land use were used to predict concentrations of TDP in overland flow from non-manure covered areas. Concentrations in runoff for manure-covered areas were computed from predicted cumulative flow and elapsed time since manure application, using field-specific manure spreading data. Base flow TDP was calibrated from observed concentrations using a temperature dependent coefficient. An additional component estimated loading associated with manure deposition on impervious areas, such as barnyards and roadways. Daily base flow and runoff volumes were predicted for each 10-m cell using the Soil Moisture Distribution and Routing Model (SMDR). For each cell, daily TDP loads were calculated as the product of predicted runoff and estimated TDP concentrations. Predicted loads agreed well with loads observed at the watershed outlet when hydrology was modeled accurately (R2 79% winter, 87% summer). Lack of fit in early spring was attributed to difficulty in predicting snowmelt. Overall, runoff from non-manured areas appeared to be the dominant TDP loading source factor. More information can be found in Hively et al. (2005). The full paper is in press (Hively et al. 2006)

Impact

The procedures were included as part of the highly-sophiscated computer technology, NYCDEP is developing and applying land (terrestrial) and reservoir models to support long-term watershed management and ongoing reservoir operations. Terrestrial models simulate water and nutrient loadings from the land area draining into the reservoirs, and apply relevant site conditions such as weather, watershed soils and topography, land use and watershed management. Reservoir models simulate in-lake water levels and flows; vertical temperature ranges; and nutrient and chlorophyll levels as a function of weather, reservoir depth, and nutrient loadings. Linking the two models provides a powerful tool for simulating the effects of weather, land use, watershed management, and reservoir operations on water quality in the City’s 19 reservoirs

Students involved

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